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recognizes this more fully than the Pope. Monseigneur Capel was his forerunner and observer in this country. Protestantism does not yet fully realize the near approach of her own charming nuptials, she is so busy with the minor details and with apologies for her careworn appearance and attitude of surrender ; but Reason and Rome are alert, and both know that the day approaches when they will be the only two real contestants left in the field.

HELEN H. GARDENER.

IV.

EARTHQUAKE STUDIES.

THE physical history of every land has left many curious traces in the vernacular of its inhabitants, and, from the contemporary language of our own country, the Max Müllers of the future would readily infer that the home of the Anglo-Saxon race, and all its parent nations, must for ages have been a sea-girt, storm-swept, but almost entirely non-volcanic region. The Spanish Americans have some twenty terms for as many distinct varieties of earthquakes ; we have hardly two, but we have at least two dozen words for all possible disturbances of the atmosphere, besides the synonyms borrowed from the mariners of foreign seas—the Chinese typhoons, the West Indian tornadoes, the monsoons of the Indian Ocean. In the same way, yearly visits to the Iceland seal-cliffs have enriched our nomenclature for the phenomena of the Arctic seas, and our American experience will yet give us a chance to enlarge our vocabulary of earthquake terms.

The completion of the Manzanillo branch of the Mexican Central Railroad will considerably promote that chance. The advocates of the "Subsidence Theory" distinguish between the jars produced by the occasional collapse of the primary rocks and the more frequent upheavals caused by the explosion of expansive vapors, and the coast regions of Colima and Michoacan are chronically subject to the latter kind of disturbances. In 1759, the subterranean furnaces of Central America seemed to have suffered an obstruction of their usual vents, and the volcanic regions of the Pacific Slope were agitated for weeks, till at last the pent-up forces exploded in the plains of Michoacan. A group of new hills rose like bubbles from a vat of seething pitch, and Mount Jorullo, the highest of the erupted mountains, became an active volcano, and continues to rise under the accumulation of its cinder hillocks. The others collapsed to the level of the Malpais, the volcanic "Badlands," of Michoacan, and it would seem as if the subterranean channels had again become partially obstructed, as their ejections force their upward way with a violence which every now and then jars the hills in a circle of half a hundred miles around the remaining vent. Near the village of Mescalita, southwest of the Badlands, the old military road to the Pacific crosses the famous Barranca of Santiago, an apparently bottomless chasm, receiving the drainage of several dozen lateral ravines, and near the brink of that abyss the traveler need rarely linger for more than a week to hear the boom of a rock-avalanche, either following or preceding the tremor of a volcanic concussion. Few stone walls have resisted those concussions, judging from the number of ruins and the prevalence of log cabins in a region where stone

buildings were once as common as in the neighborhood of Cadiz. The frequency of those shocks has taught the natives some useful lessons.

They have learned to diagnose the first symptoms of a dangerous earthquake. In nineteen out of twenty cases the degree of that danger is indicated by the *scale* of the vibrations, the increasing or decreasing violence of the successive shocks. In the former case the first concussion, or series of concussions, is a warning of worse things to come ; in the latter a rule, with few exceptions, encourages the hope that Seismos has done his worst for that day, and probably for that month. For the same rule holds good for a protracted series of tremors. If a period of earthquakes begins with a day of destructive shocks, followed by a week of feeble reverberations, the omen gives promise of peace, and Wiggins' prediction of a very characteristic period of that sort being but the prelude of a far more ruinous upheaval would have made few dupes in any part of Spanish America.

Experience has also proved that earthquake shocks, as a rule, do not spread in eddies. The violence of the upheaval at any given point cannot be measured by the distance from an initiative center of the disturbance. The tremor may be felt with equal distinctness along a number of divergent lines, extending for a hundred miles or more from a common focus, but sparing the intermediate regions—regions of a geological character often apparently identical with that of the upheaved districts. A seismic wave may traverse a mountain range at right angles with the main axis of its strata, break down cliffs which a ton of dynamite would have failed to move, and a few miles farther to the left or right spare a slender pinnacle of the same mineralogical formation. Even narrower areas have such safety-points. The great earthquake of 1812 spared the Calle de San Martin, a straggling hill street of Caracas, and spared it again in 1826, when in streets and lanes on both sides of the favored district not a house was left standing. On the small island of Sumbawa, a few villages on the north coast have thus far escaped the repeated cataclysms that rent the very rocks of the surrounding hills. A press-dispatch from Charleston ("New York Star," September 5), mentioned a building, considered a weak structure, which nevertheless escaped without any injury, while east, north and west of that building (on a corner of Market Street), massive blocks had been turned into a chaos of *débris*.

It is true, though, that the criteria of weakness or strength in resisting a tornado do not apply to the danger from earthquake shocks. The Charles-tonians wondered at the utter destruction of massive brick buildings and the comparative immunity of frame houses, which a hurricane would have carried away like so many bundles of wheat straw. The explanation is, that an earthquake lacks the propulsive horizontal power of a storm, while its upheaval force is so absolutely irresistible that *weight* counts for nothing in securing the safety of a building. A light *coherent* structure will escape where a mountainous mass of brick would be shaken to pieces as easily as a heap of cobble-stones. A well-joined log cabin could be made almost earthquake-proof. Its chimneys might collapse at the first shock, but the walls would hold their own, and the safety of the low and squat stone buildings of Spanish American earthquake cities is founded on the circumstance that a low wall of broad, flat stones can

be rocked like a ship in a storm without outswaying its equilibrium. But if an exceptional concussion manages to accomplish that feat, such houses become the grave of all who have trusted to the safety of their massive walls; hence the fearful destruction of life in the South European and South American cities, which have now and then been visited by the resistless shocks of such earthquakes—differing from a common tremor as the rush of the maelstrom differs from the ripple of a summer sea.

That concussions of that sort have caught thousands of human beings asleep might seem a conclusive proof that the caprices of the Titan, Seismos, cannot be predicted for a single hour; yet those who have suffered the most from his spite would be the last to admit that any serious earthquake ever failed to send its warnings before, though they might confess that the symptoms of those warnings are neither infallible nor free from the ambiguity of certain weaker prognostics. A low barometer, for instance, may portend a storm, a period of tedious thaws, or a first-class earthquake. In a volcanic region a premonitory shock may be the death-knell of thousands, or as insignificant as a puff of wind on a breezy sea-coast. The "restlessness of animals" may indicate all sorts of things—a storm, a forest fire, a heavy thunder-shower. The invasion of their eyries often sets water-fowl circling about the sky with ominous cries. The "sudden silence of locusts and crickets," which a Virginia correspondent of the New York "Staats Zeitung" noticed on the evening of the Charleston earthquake, is as often observed in any chilly night, or before a heavy gale. Domestic animals may become "restless" from a mere disorder of the digestive process.

The *niebla*, or earthquake haze, is a less ambiguous symptom. Both before and during volcanic disturbances, a curious, wide-spread mist has been so often observed in the plutonic mountain regions of Spanish America that the natives have come to regard it as an almost infallible omen either of an earthquake or an unusually violent eruption. On the last day of August, it was observed all over the western Alleghanies, as far west as Huntsville, Alabama, as well as all along the coast-waters of our Atlantic border. Captain Smitherick, of the American bark "Robert Dixon," felt a shock as if the vessel had grounded, and remarks that "for a day or two the weather had been strangely murky, seeming to portend the approach of a storm." At the mouth of the Chesapeake Bay the United States revenue-cutter "Ewing" was overtaken by a storm, coming and going in abnormally fitful blasts, while the horizon was clouded by a grayish haze, which reminded one of the officers of the appearance of the sky on the eve of the great eruption of 1868, when a tidal wave nearly swamped the United States steamer "Wateree," then off Arica, on the coast of Peru. Before the earthquake of 1826, a similar mist was for weeks observed along the west coast of South America, and as far north as the West Indian archipelago, where the creoles regarded it with growing alarm, dreading another outbreak of the volcano which nearly exploded the island of Saint Vincent in 1812. In the volcanic uplands of Java, where it is an almost yearly phenomenon, the natives unhesitatingly ascribe it to the action of subterranean fires; and it should, indeed, be presumed that the expansive vapors, upheaving a continent, would now and then succeed in forcing their way through the fissures and caverns of

a mountain region ; and it is a curious fact that the appearance of the earthquake haze often coincides with the sudden outburst of hot springs (or geysers, as in the valley of the Yellowstone).

It is not easy to see how either phenomenon could be explained by the impending "collapse of the primary rocks"—owing to the gradual contraction of the earth's crust, which the advocates of the subsidence theory identify with the main cause of seismic disturbances. Nor could the subsidence of subterranean strata explain the peculiar long-continued rhythmical vibrations, which so often follow a severe earthquake shock, and which the originator of a more plausible theory explains as follows: "When the subterranean fires effect an irruption at the bottom of the sea, a vast volume of steam is evolved explosively, and being forced against the deep and cold water of the sea, a blow of the most tremendous sort is thus given at the volcanic focus, and transmitted outwardly as the earthquake shock. The surface of the ignited material, though now cooled down below the point at which steam can be generated rapidly, still keeps up a fierce ebullition, which is transmitted as the vibration after the shock."—(Mr. Henry Mallet's report to the British Association.)

Whenever such steam explosions force their way into the rock-caverns of the nether world, the interaction of the irruptive force and the resisting pressure of the imprisoned air would explain the still more curious phenomenon of subterranean thunders which have often almost deafened the inhabitants of volcanic districts, as in 1842, when the Roars (*los Bramidos*) of Vera Paz stamped the natives of a Guatemala mountain village, and continued for nearly half a month with ever increasing violence, though attended only by trifling tremors of the upper rock strata.

The progress of geology has encouraged the hope that its revelations will yet enable us to predict earthquakes with nearly as much certainty as our meteorologists have already learned to predict atmospheric disturbances. The possibility of such forecasts would, however, depend on a more precise determination of the primary causes of seismic phenomena, and an important step in that direction would be the explosion of sham theories, and what might be called the compromise tenets, attempting to bridge the chasms between science and mythology.

The serious refutation of such self-contradictory cant as the ratiocination of the astrological oracle-school would be an insult, not only to science, but to the memory of those quasi-scientific empirics who for hundreds of years made the aspect of the firmament the basis for speculations on all sorts of natural and supernatural events, and could hardly have failed to recognize the synchronism of planetary conjunctions and such notable phenomena as earthquakes and earth-shaking hurricanes. But science may find it a harder task to explode the fallacies of logical inferences based on erroneous premises, and which, in spite of the evident unsoundness of that basis, still continue to obstruct the path to the goal of a tenable exegesis. That exegesis may prove to be at variance with all sorts of established dogmas; but, like the Copernican theory, it will prevail by solving many riddles.

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